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ORIGINAL ARTICLE

Diagnosis of recurrent cholesteatoma using diffusion weighted MRI

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KEYWORDS

Mastoidectomy;
Cholesteatoma;
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Abstract *Objective:* To assess the role of diffusion weighted images (DWI) MRI in differentiating post mastoidectomy recurrent cholesteatoma from infected postoperative granulation tissue.
Materials and methods: 13 patients who performed mastoidectomy for previous cholesteatoma that now presented with clinical and CT signs of recurrence were referred to perform non contrast MRI using T2 and DWI sequences in order to differentiate recurrent cholesteatoma from infected postoperative granulation tissue.
Results: 8 patients showed MRI evidence of recurrent cholesteatoma, findings were confirmed intra-operative, -ve cases showed good response on medical treatment with regression of their clinical and radiological signs.
Conclusion: DWI MRI accurately differentiates recurrent cholesteatoma from infected post operative granulation tissue avoiding unnecessary second look operations.

1. Introduction

Cholesteatoma is an epidermal cyst of the middle ear or mastoid air cells and is filled by desquamated keratin. A cholesteatoma is eradicated from the temporal bone by surgical resection by either radical or modified radical mastoidectomy. The choice of surgical approach depends upon the extension into the middle ear and mastoid cavity and the status of the ossicular chain and tympanic membrane (1). A major disadvantage is the narrow surgical field, a feature that is associated with a high rate of residual and recurrent cholesteatomas (35% and 18%, respectively) (2).

It is difficult to clinically diagnose a recurrent cholesteatoma in a closed postoperative cavity except if a typical white mass is seen under the drum membrane. Thus, second look operations are the accepted management by many otologists. These procedures can be associated with postoperative complications as infection, bleeding, delayed healing, disequilibrium, taste disturbances, hearing loss and facial nerve paralysis. In addition, they are done using general anesthesia with possible anesthesia-related complications (3).

Computed tomography (CT) has been considered the imaging technique of choice for the evaluation of middle ear cholesteatoma in the preoperative cases, however it cannot, differentiate between cholesteatoma, granulation tissue,

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retained secretions or cholesterol granuloma in the postoperative bed (4).

Magnetic resonance imaging (MRI) showed good evaluation capability in the evaluation of the recurrent cholesteatom. Various MR imaging protocols have been proposed that are mainly based on the use of delayed gadolinium-enhanced T1-weighted sequences, diffusion weighted imaging (DWI) sequences, or a combination of both techniques (4).

DWI images are known to have a low spatial resolution, a high-resolution T2-weighted sequence is required to correlate DWI findings with the patient's anatomy. Delayed postcontrast T1-weighted sequence did not show significant increase in sensitivity or specificity in diagnosis of recurrent cholesteatoma (4).

The echo-planar (EP) is the standard technique used in DWI, often used for the early diagnosis of cerebral infarction. In the temporal bone, EP DWI showed limited diagnostic value because of susceptibility artifacts. Non-EP DW imaging which has a slightly longer acquisition time but much less susceptibility artifacts showed a higher sensitivity and specificity for cholesteatoma diagnosis than EP DWI (5).

The aim of this study was to assess the accuracy of noncontrast MRI with DWI to diagnose recurrent cholesteatoma.

2. Materials and methods

2.1. Study population

After the approval of our ethical committee and obtaining informed consent from all patients, thirteen patients (6 male and 7 females) with age range from 23 to 55 years with mean age of 37 years were included in this study between August 2013 and June 2014. All patients previously resected cholesteatoma of the middle ear, now are showing suspicious partial or complete opacity in the operative bed on computed tomography (CT) performed due to recurrence of discharge, pain or progressive hearing loss. The mean interval between the mastoidectomy operation and the CT assessment was 30 months, all patients were further assessed by MRI imaging of the petrous temporal bone on an average of 1-3 weeks after the CT examination, they all tolerated the study that did not exceed about 15 min from the patient's positioning, there were no need for sedation or anaethesia. Positive cases were referred for second-look surgery, while -ve cases received medical treatment and then were followed up using the CT scanning.

2.2. CT protocol

CT examinations of the petrous bone were performed on a 128-section CT scanner (Phillips Ingenuity PET/CT Scanner, Netherlands) with 0.32-mm section thickness. Scan conditions were 140 kV, 300 mA s, and 1 s/rotation in helical mode. All studies were performed without contrast and included the entire petrous bone, reconstruction of the axial and coronal sections was done and all images were evaluated by the same radiologist.

2.3. MRI protocol

MRI was performed using a superconductive Philips scanner (Intera, 1.5Tesla, Philips Healthcare, Best, The Netherlands), following the patients' informed consent and exclusion of contraindications. The following sequences were acquired on the middle ear using an 8 channel head coil and applying the Parallel SENSE imaging is used to obtain better resolution, faster dynamic scans and to reduce susceptibility artifacts.

1. 3D CISS (constructive interference in steady state) with a gradient echo component
   tilt angle: 70°, slice thickness: 0.7 mm, repetition time (TR): 11.5 ms, echo time (TE): 5.75 ms, SENSE factor 2, field of view: 230 mm. Acquisition time 3 min and 50 s.
2. Axial nonecho-planar single shot turbo spin echo diffusion-weighted imaging:
   2.5 mm thick axial slices, TE: 98 ms, TR: 2000 ms, SENSE factor 2, diffusion factor: B 1000 s/mm^2, FOV: 230 mm. Acquisition time 2 min and 50 s,
3. Coronal T2-weighted coronal spin echo (TSE).
   TR/TE, 5270/119 ms; matrix, 512; section thickness, SENSE factor 2, 3 mm; field of view, 230 mm. Acquisition time 3 min and 12 s.

3. Image analysis

CT and MRI images were reviewed by one radiologist not informed about the results of surgery. cholesteatoma was diagnosed by the presence of suspicious opacity in the middle ear on CT. Cholesteatoma was diagnosed on MRI in the presence of high signal intensity on T2-weighted sequences, showing high signal intensity and diffusion restriction on diffusion-weighted imaging without calculation of the ADC value yet the ADC maps were used to exclude the presence of T2 shine through effects. No merging between the CT and MRI images was done. Statistical analysis was done using SPSS 20.0 statistical software (SPSS Inc., Chicago, IL, USA).

4. Results

Thirteen patients (6 males and 7 females) who had been operated for previous cholesteatoma (5 were right sided and 8 were left sided), have now presented with clinical and CT signs of recurrence, noncontrast MRI showed recurrent cholesteatoma (Fig. 1) in 8 patients (61.5%) 3 were right sided and 5 were left sided while 5 patients showed no signs of recurrence (38.5%) 2 were right sided and 3 were left sided, +ve cases underwent surgery that confirmed the diagnosis in all cases with sensitivity, specificity, +ve and -ve predictive value of 100%. The 5 -ve cases were treated conservatively and followed up clinically and by CT scans (Table 1), all showed regressive course that confirmed that the primary opacities seen were mostly postoperative granulation tissue (Fig. 2). the average size of cholesteatomas detected by DWI was ±4.8 mm, we did not encounter lesions less than 3 mm, there were no false positive or negative cases in this study group.

5. Discussion

Cholesteatomas are either primary or secondary acquired chronic inflammatory lesions of the middle ear and mastoid. The destructively and erosive epithelium requires complete surgical excision. The pathogenesis of cholesteatoma as well as the

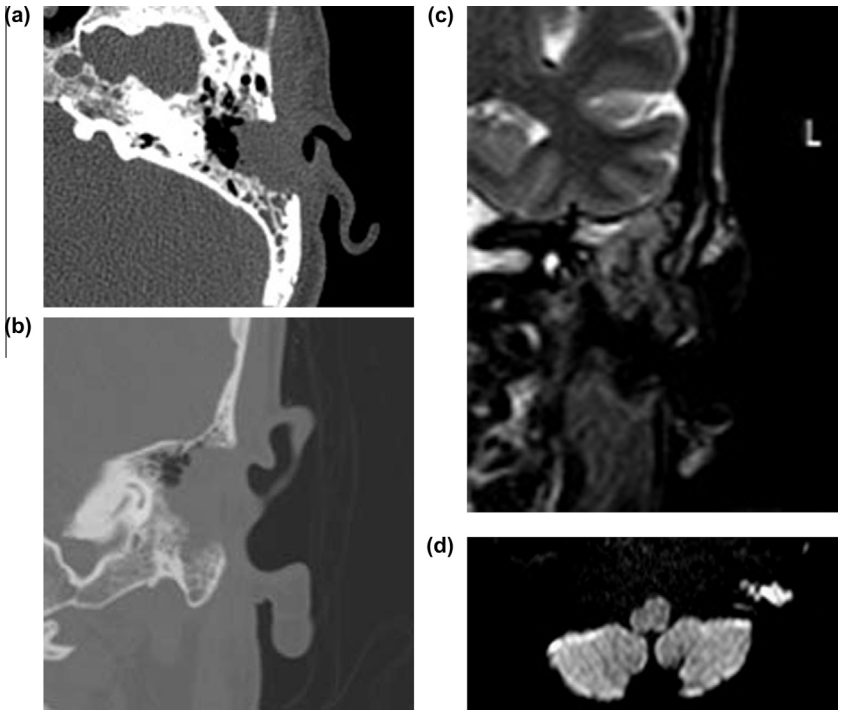

Fig. 1 (a–d) A 39 years patient underwent left sided mastoidectomy, then 2 years later he developed recurrent discharge and pain, CT scan (a) axial and (b) coronal scans showed irregular soft tissue lesion in the operative bed with areas of bony erosions, MRI (c) T2 image showed irregular hyperintense soft tissue lesion seen in the operative bed that shows diffusion restriction in the DWI image (d), diagnosis is recurrent cholesteatoma, findings were confirmed by surgery.

incidence and reasons for residual and recurrent lesions are still under research (6).

While CT is the most frequently used imaging modality for postoperative diagnosis, a mass is found in the typical location associated with bone destruction then a cholesteatoma is assumed, yet findings are not specific, infected granulation tissue and retained secretions show the same CT features (7).

MR imaging is superior than CT in tissue characterization. For diagnosis of recurrent cholesteatoma, DWI has proved their high diagnostic value. Water molecules in cholesteatomas show diffusion restriction giving the high signal in the DWI images (8).

DW EPI has been shown to be accurate in differentiating inflammatory tissue from cholesteatoma in the non-surgically treated middle ear, as cholesteatoma demonstrates a clear hyperintensity on DW EPI sequences in contrast to inflammatory tissue. Several reports have discussed the value of DW EPI and late post-gadolinium T1-weighted sequences in the detection of pre-second-look residual cholesteatoma and postoperative recurrent cholesteatoma. No false-positive findings have been reported in the literature, so hyperintensity on DW images can be considered diagnostic for cholesteatoma. It is clear that DW EPI has a role in the visualization of the usually quite large recurrent or relapsing

Table 1 Correlation between CT and MRI results with the operative data.

Cases	Primary lesion size by CT in mm	Recurrent cholesteatoma diagnosed by MRI	Operative confirmation	Lesion size in follow-up CT in mm	Cholesteatoma size by DWI MRI in mm
Case 1	15	Yes	Yes		8
Case 2	10	Yes	Yes		6
Case 3	7	No	No	2	0
Case 4	8	Yes	Yes		5
Case 5	7	Yes	Yes		3.5
Case 6	9	Yes	Yes		4
Case 7	8	Yes	Yes		4
Case 8	7	No	No	3	No
Case 9	6	No	No	1.5	No
Case 10	7	Yes	Yes		3
Case 11	6	No	No	2	No
Case 12	10	Yes	Yes		5
Case 13	9	No	No	2.5	No

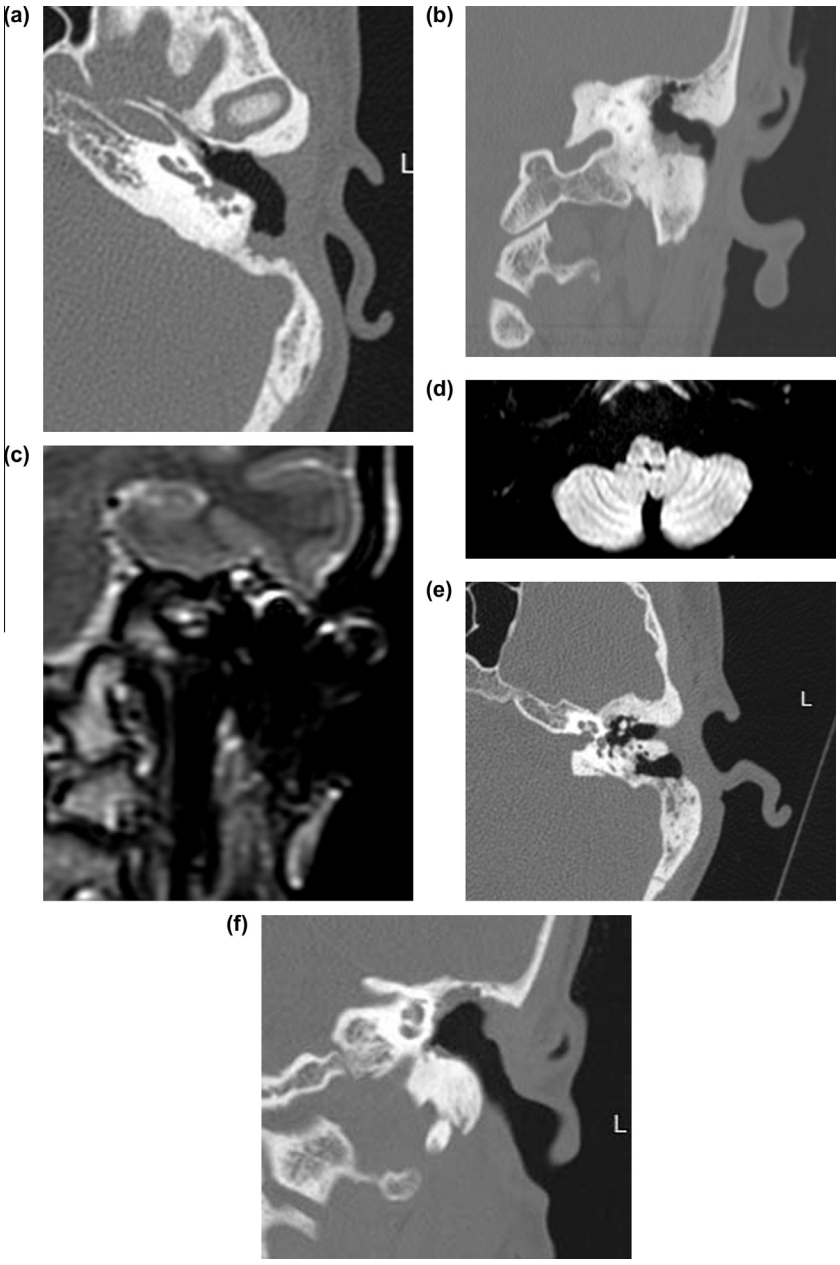

Fig. 2 (a–f) A 45 years old patient underwent left sided mastoidectomy was referred 15 months later due to ear ache and discharge, axial (a) and coronal (b) CT scans showed irregular erosive soft tissue lesion in the operative bed, T2 coronal MRI (c) and DWI MRI (d) showed mild irregular mucosal thickening in the operative bed with no diffusion restriction likely representing infected granulation tissue, after conservative management follow up axial (e) and coronal (f) CT showed regression of the inflammatory process excluding the possibility of recurrent cholesteatoma.

cholesteatoma. DW EPI, however, fails to demonstrate middle ear cholesteatoma with a size smaller than 5 mm due to susceptibility artifacts, lower imaging matrix and relatively thick slices. Recent reports have highlighted the use and value of a non EPI-based DW sequence in the diagnosis of primary middle ear cholesteatoma and postoperative recurrent cholesteatoma (9).

During the past decade, fast spin-echo-based non-EPI DWI techniques have been developed by different MR imaging vendors. These techniques include single-shot turbo spin-echo DWI, half-Fourier acquisition single-shot turbo spin-echo (HASTE) DWI (Siemens Medical Solutions, Erlangen, Germany), PROPEL LER DWI, BLADE DWI (Siemens Medical Solutions), and multi-shot DWI turbo spin echo. These sequences minimize most susceptibility artifacts and allow thinner sections and higher imaging matrices, yielding sensitivities in the 90–100% range for lesions as small as 2 mm. In comparison with EPI DWI, these non-EPI DWI techniques improve sensitivity for the detection of lesions smaller than 5 mm and allow better lesion delineation (10).

The main diagnostic criterion for cholesteatoma at DWI is lesion hyper-intensity, compared with the signal intensity of

brain, on $b = 0\ s/mm^2$ images that persists or increases on high b value (800–1000 s/mm^2) images. Although sometimes useful for diagnosis, ADC values have not been used as a diagnostic criterion. No clear-cut values have yet been established to differentiate between cholesteatoma and other inflammatory lesions (10). Even when non-EPI DWI techniques are used to screen for residual disease, very small lesions (< 2–3 mm) may be missed. Leaving such small cholesteatomas is considered safe, and some authors propose follow-up studies to detect these lesions once they have grown larger (1). The necessity for such follow-up studies, and the interval at which they should be performed, are issues still to be determined. Although not yet defined, this interval should be shorter in children, given the faster growth rate of these lesions (11).

The study results strongly correlated with recent studies on diffusion-weighted magnetic resonance imaging showed high sensitivity (85–90%), specificity (92–100%), positive predictive value (92–100%) and negative predictive value (92%) in the diagnosis of recurrent cholesteatoma after mastoidectomy surgery (12). McMurphy and Oghalai (13) reported that CT alone can be misleading in postoperative states. They considered MRI essential for differentiation between granulation tissue, cholesteatoma and brain herniation.

The results also correlated with those done by Emonot et al. (14) that showed sensitivity of 79%, specificity 95% and positive predictive value 90% for diffusion weighted MRI image for diagnosis of recurrent cholesteatoma, while Ilica et al. (15) showed sensitivity of 94%, specificity and positive predictive value of 100% of diffusion weighted MRI in diagnosis of cholesteatoma.

The study group did not show any false negative cases, this could attributed due to the small number of referred cases, lesion sizes were higher than 3 mm, the -ve cases received medical treatment and all improved on follow up CT scans.

Our study had some limitations, low number of cases, the diagnosis was made by one radiologist with no interobserver variation assessment, no comparison made was done in between the different DWI sequences and the -ve cases were diagnosed by decrease in CT size during follow up not by surgery.

In conclusion DWI MRI proved to be a very valuable tool to diagnose recurrent cholesteatoma eliminating the need for second look surgery in cases of infected postoperative granulation tissue.

Conflict of interest or financial support

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